The Soil Moisture Active Passive Mission (SMAP) Science Data Products:

Results of Testing With Field Experiment and Algorithm Testbed Simulation Environment Data

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Talk Outline

1. Derivation of SMAP basic and applied science requirements from the NRC *Earth Science Decadal Survey* applications

2. Data products and latencies

3. Algorithm highlights

4. SMAP Algorithm Testbed

5. SMAP Working Groups and community engagement

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Project/Mission Overview—Mission Context

US National Research Council Report: "Earth Science and Applications from Space: National Imperatives for the next Decade and Beyond"

(National Research Council, 2007) http://www.nap.edu

SMAP is one of four missions recommended by the NRC "Decadal Survey" for launch in the first tier

Feb 2008: NASA announces start of SMAP project

SMAP is a directed-mission with heritage from Hydros ESSP

Tier 1: 2010–2013 Launch
Soil Moisture Active Passive (SMAP)
ICESAT II
DESDynI
CLARREO
Tier 2: 2013–2016 Launch
SWOT
HYSPIRI
ASCENDS
GEO-CAFE
ACE
Tier 3: 2016–2020 Launch
LIST
PATH
GRACE-II
SCLP
GACM
3D-WINDS

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Science Requirements

DS Objective	Application	Science Requirement
Weather Forecast	Initialization of Numerical Weather Prediction (NWP)	Hydrometeorology
Climate Prediction	Boundary and Initial Conditions for Seasonal Climate Prediction Models	Hydroclimatology
	Testing Land Surface Models in General Circulation Models	
Drought and Agriculture Monitoring	Seasonal Precipitation Prediction	Hydroclimatology
	Regional Drought Monitoring	
	Crop Outlook	
Flood Forecast Improvements	River Forecast Model Initialization	Hydrometeorology
	Flash Flood Guidance (FFG)	
	NWP Initialization for Precipitation Forecast	
Human Health	Seasonal Heat Stress Outlook	Hydroclimatology
	Near-Term Air Temperature and Heat Stress Forecast	Hydrometeorology
	Disease Vector Seasonal Outlook	Hydroclimatology
	Disease Vector Near-Term Forecast (NWP)	Hydrometeorology
Boreal Carbon	Freeze/Thaw Date	Freeze/Thaw State

Requirement	Hydro-Meteorology	Hydro-Climatology	Carbon Cycle	Baseline Mission	
				Soil Moisture	Freeze/Thaw
Resolution	4–15 km	50–100 km	1–10 km	10 km	3 km
Refresh Rate	2–3 days	3–4 days	2–3 days(1)	3 days	2 days(1)
Accuracy	4–6% **	4–6%**	80–70%*	4%**	80%*

(*) % classification accuracy (binary Freeze/Thaw)
(**) [$cm^3\ cm^{-3}$] volumetric water content, 1-sigma

(1)North of 45N latitude

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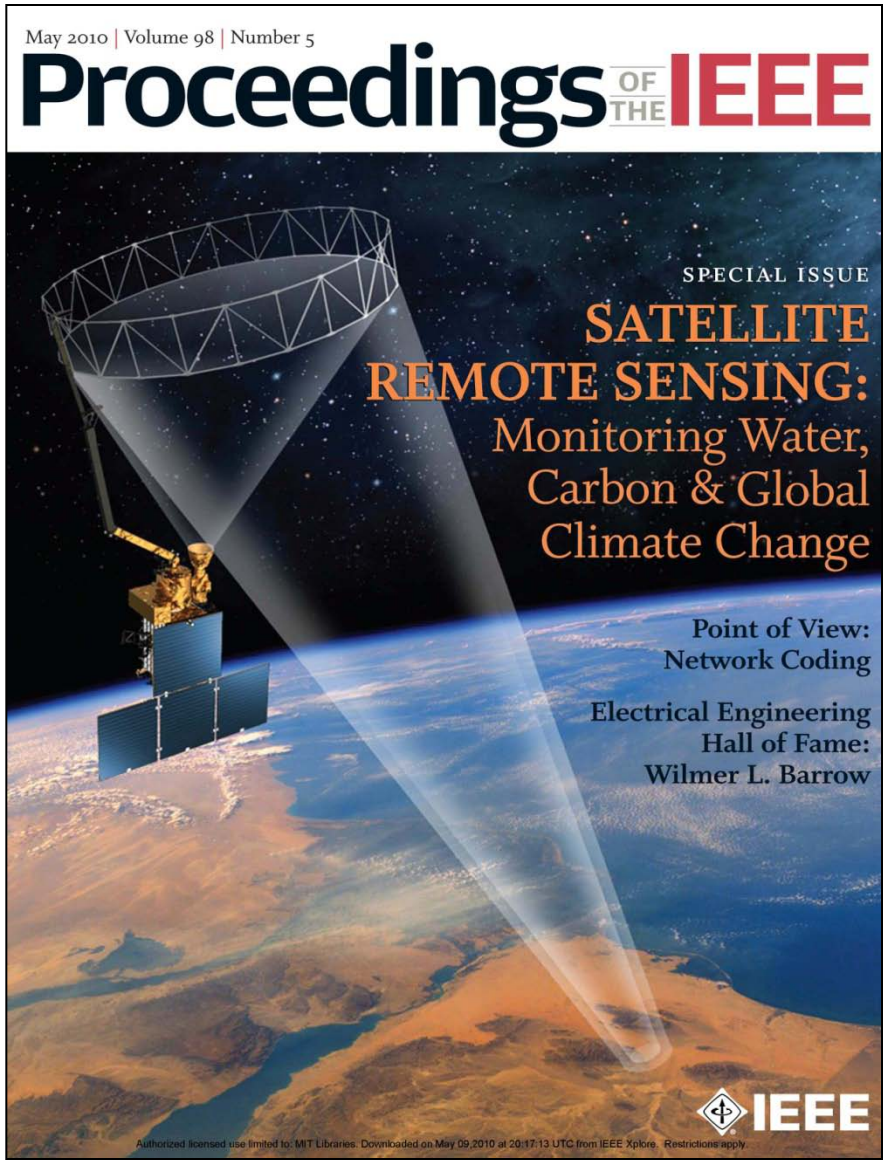
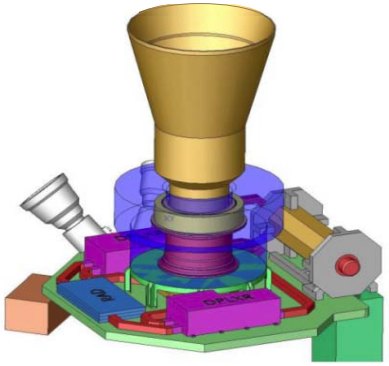
SMAP Mission Concept



- L-band unfocused SAR and radiometer system, offset-fed 6 m light-weight deployable mesh reflector. Shared feed for
  - 1.26 GHz dual-pol Radar at 1-3 km (30% nadir gap)
  - 1.4 GHz polarimetric Radiometer at 40 km
- Conical scan, fixed incidence angle across swath
- Contiguous 1000 km swath with 2-3 days revisit (8 day repeat)
- Sun-synchronous 6am/6pm orbit (680 km)
- Launch 2014
- Mission duration 3 years



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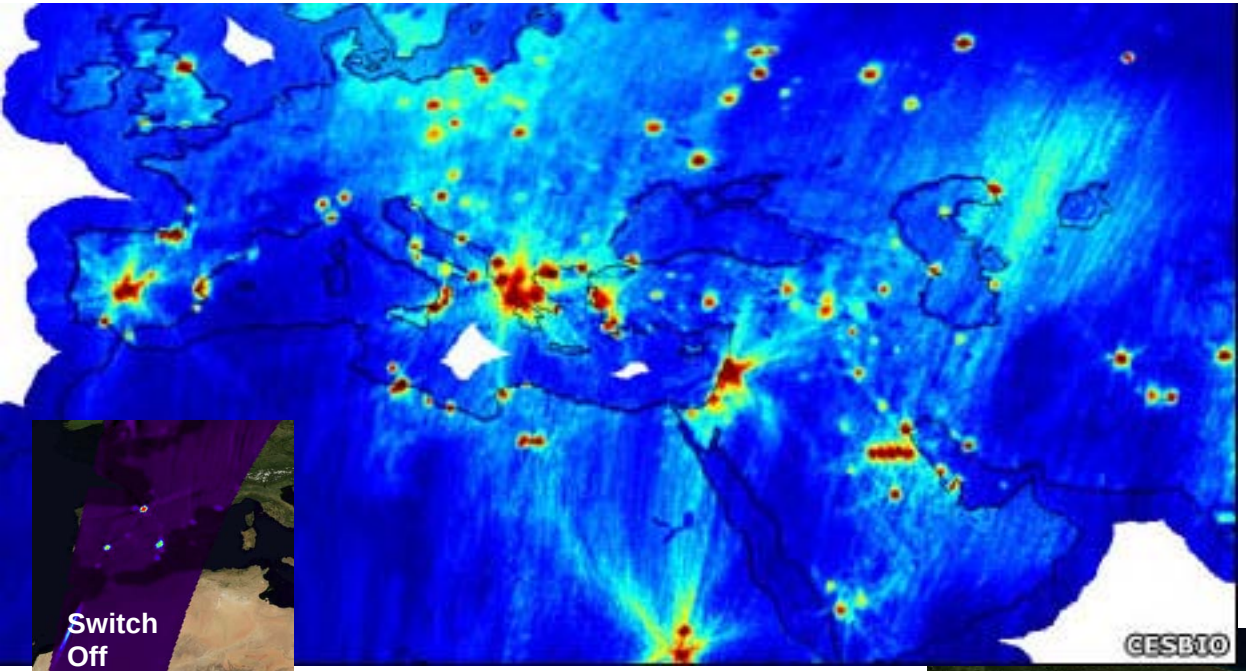
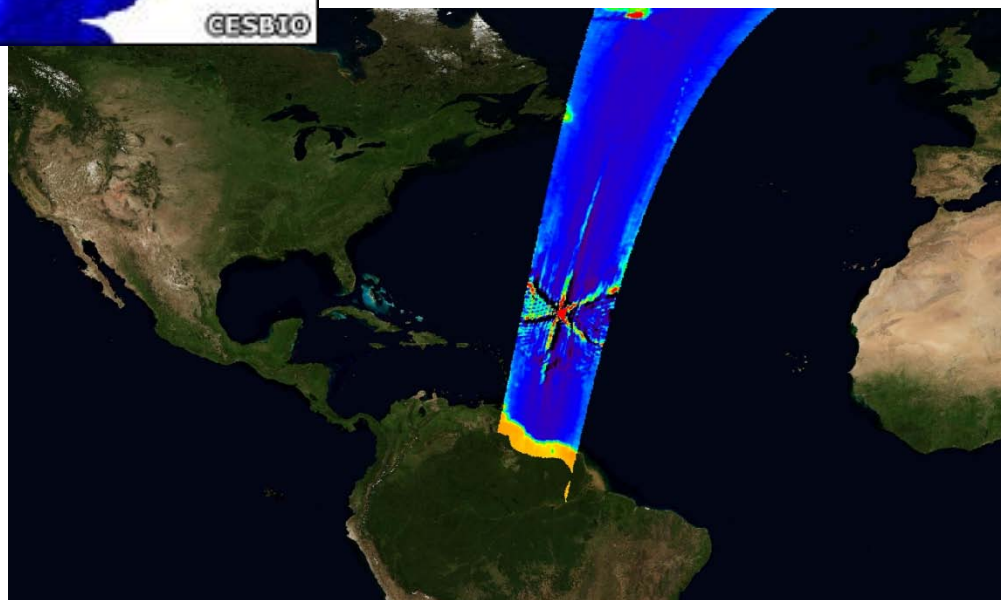
Anthropogenic Radio-Frequency Interference (RFI)



RFI is evident and wide-spread (Early Data from SMOS)

SMAP is taking aggressive measures to detect and mitigate RFI in its instrument and data processing designs.



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L-band Active/Passive Soil Moisture Mapping

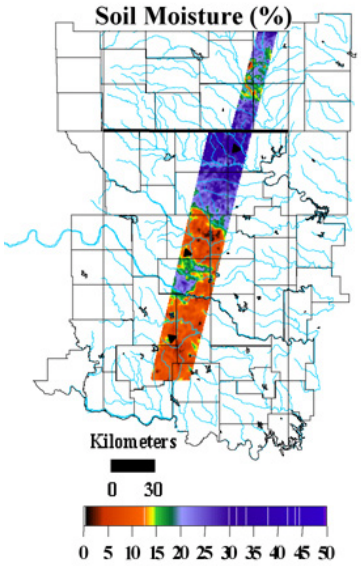
- Soil moisture retrieval algorithms are derived from a long heritage of microwave modeling and field experiments

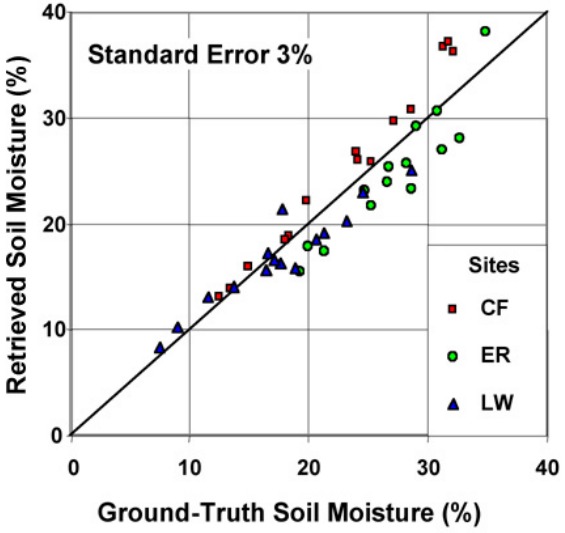
  MacHydro'90, Monsoon'91, Washita92, Washita94, SGP97, SGP99, SMEX02, SMEX03, SMEX04, SMEX05, CLASIC, SMAPVEX08, CanEx10

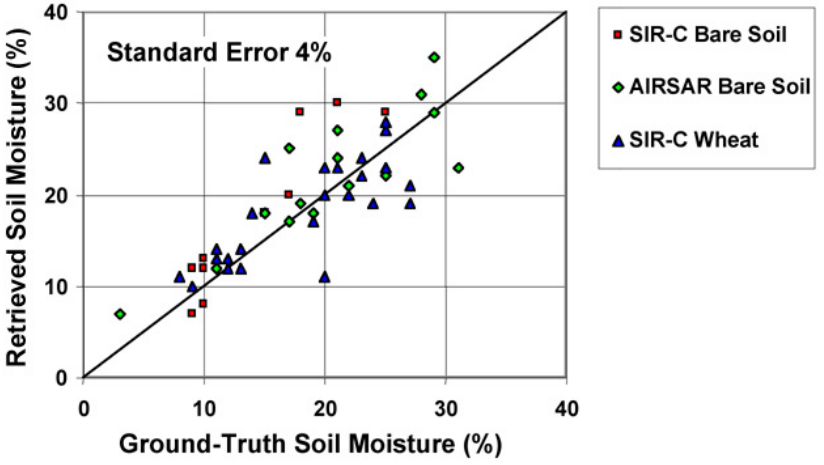
- ***Radiometer*** - High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)

- ***Radar*** - High spatial resolution (1-3 km) but more sensitive to surface roughness and vegetation

- **Combined Radar-Radiometer** product provides optimal blend of resolution and accuracy to meet science objectives







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SMAP Data Products

Data Product Short Name	Description	Data Resolution	Grid Spacing	Mean Latency*
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	-	12 hrs
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1x1 km to 1x30 km	1 km	12 hrs
L1B_TB	Radiometer T_B in Time Order	36x47 km	-	12 hrs
L1C_TB	Radiometer T_B	40 km	36 km	12 hrs
L2_SM_A	Radar Soil Moisture	1-3 km	3 km	24 hrs
L2_SM_P	Radiometer Soil Moisture	40 km	36 km	24 hrs
L2_SM_A/P	Active-Passive Soil Moisture	9 km	9 km	24 hrs
L3_F/T_A	Daily Global Composite Freeze/Thaw State	1-3 km	3 km	50 hrs
L3_SM_A	Daily Global Composite Radar Soil Moisture	1-3 km	3 km	50 hrs
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	40 km	36 km	50 hrs
L3_SM_A/P	Daily Global Composite Active-Passive Soil Moisture	9 km	9 km	50 hrs
L4_SM	Surface and Root Zone Soil Moisture	9 km	9 km	7 days
L4_C	Carbon Net Ecosystem Exchange	9 km	9 km	14 days

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L2_SM_AP Algorithm Concept

Temporal changes in T_B and σ_{pp} are related. Relationship parameter β is estimated at radiometer-scale using successive overpasses.

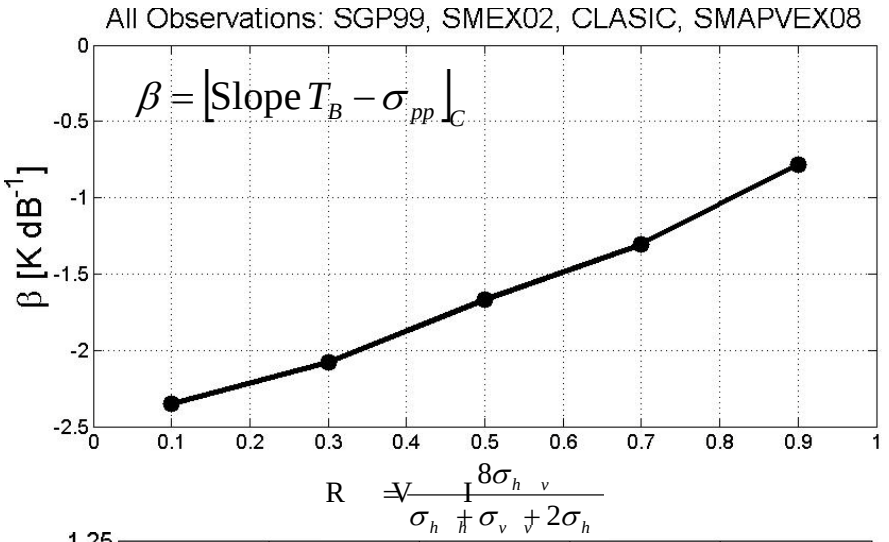
Heterogeneity in vegetation and roughness conditions within radiometer-scale are evaluated by estimating sensitivities Γ in radar cross-pol:

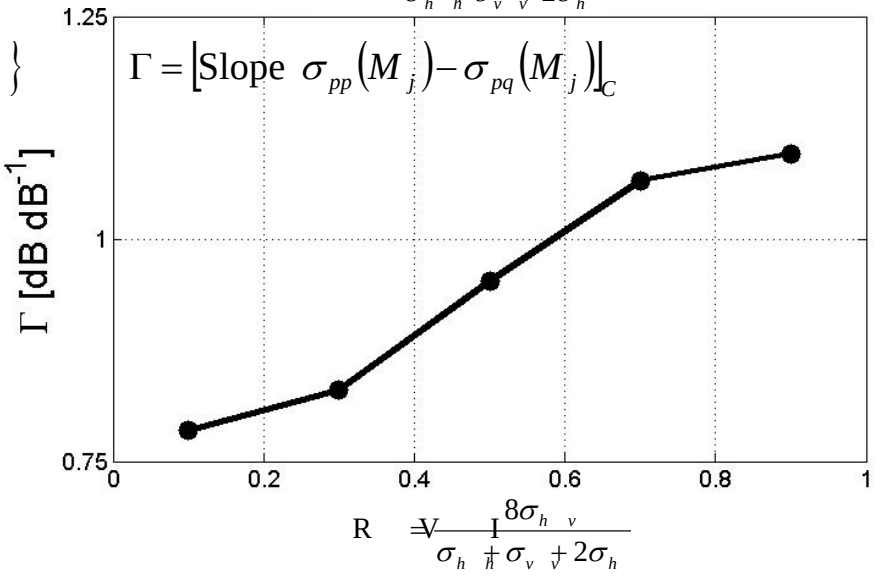
T_B-disaggregation algorithm is:

$$T_{B_p}(M_j) = T_{B_p}(C) + \beta(C) \cdot \{ [\sigma_p(M_j) - \sigma_p(C)] - \Gamma \cdot [\sigma_{pq}(M_j) - \sigma_p(C)] \}$$

$T_B(M_j)$ is used to retrieve soil moisture at 9 km (consistent algorithm and ancillary data as radiometer algorithm

Airborne observations from four field experiments with PALS combine to form test database





Source: N. Das (JPL)

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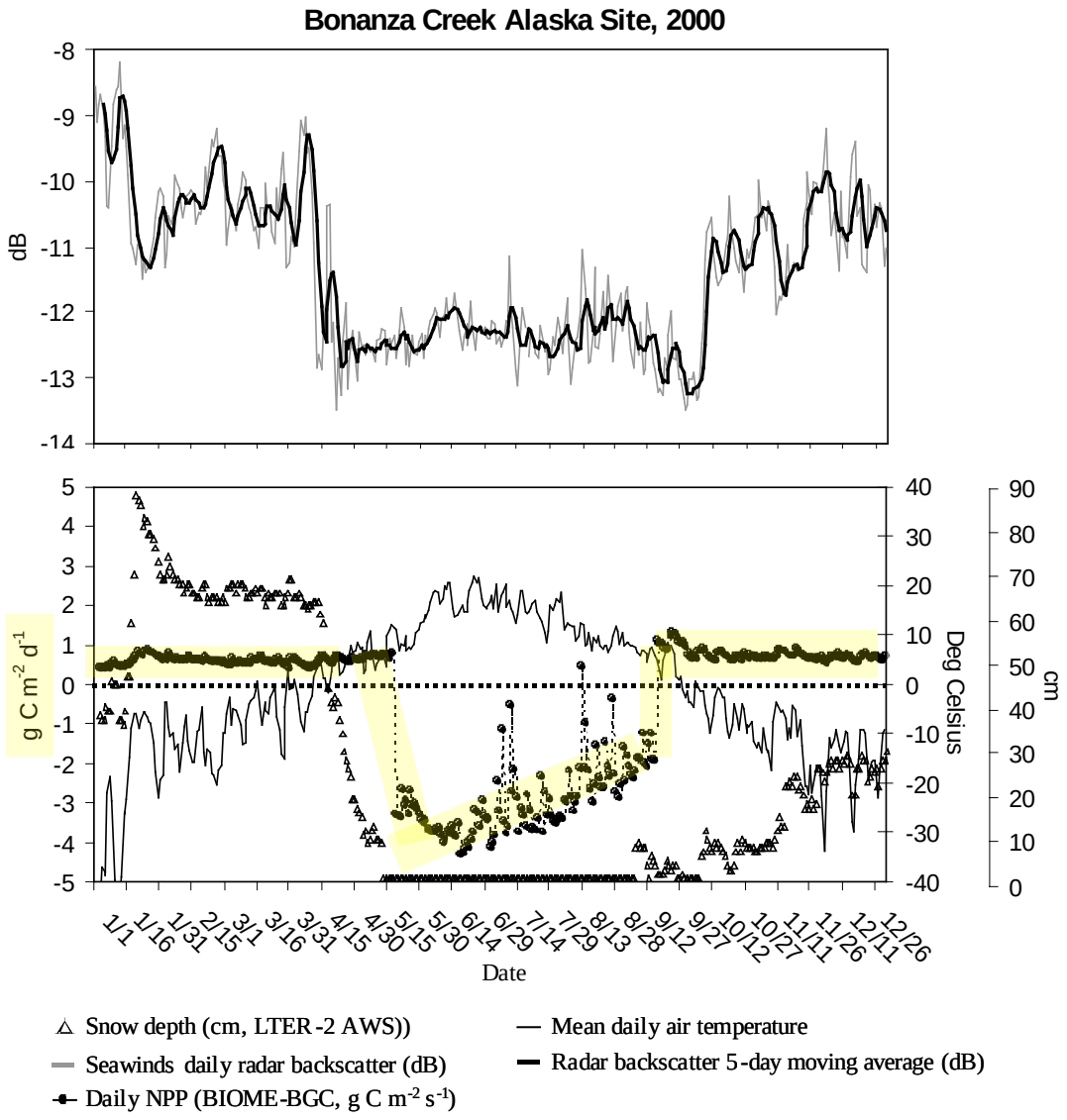
L2_FT_A Algorithm Concept



Baseline Algorithm:

$\Delta(t) = [\sigma^0(t) - \sigma^0_{fr}] / [\sigma^0_{th} - \sigma^0_{fr}]$

σ^0_{fr} = frozen reference

σ^0_{th} = thawed reference

T = threshold

$\Delta(t) > T$ (Thawed)

$\Delta(t) \leq T$ (Frozen)

Source: K. McDonald (JPL) and j. Kimball (UMT)

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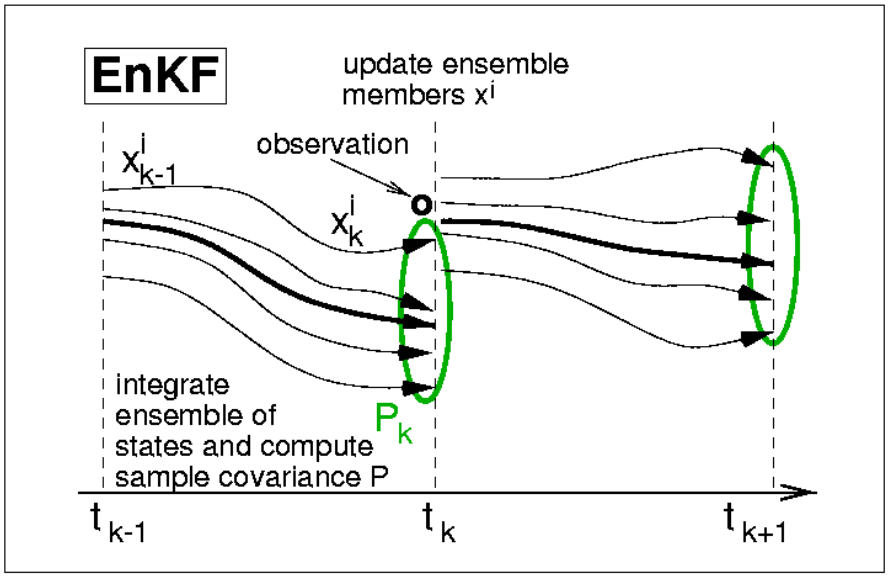
L4_SM Algorithm Concept

Main objectives:

- Provide estimates of **root zone** soil moisture (top 1 m) based on SMAP obs.
- Provide **global, 3-hourly, 9 km** surface and root zone soil moisture.

Baseline algorithm:

- Customized version of existing NASA/GEOS-5 Land Data Assimilation System
  - 3d Ensemble Kalman filter
  - Catchment land surface model



Source: R. Reichle (NASA GSFC)

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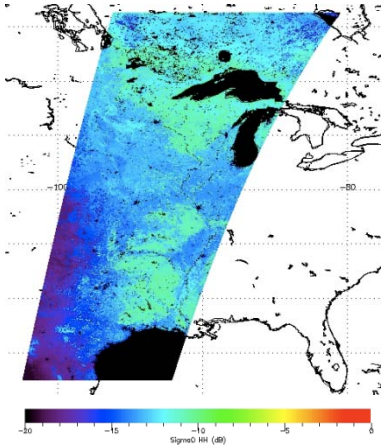
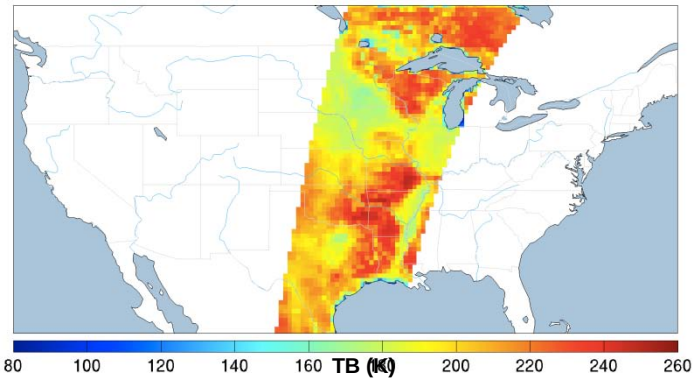
SMAP Algorithm Testbed

Simulated products generated with prototype algorithms on the SDS Testbed

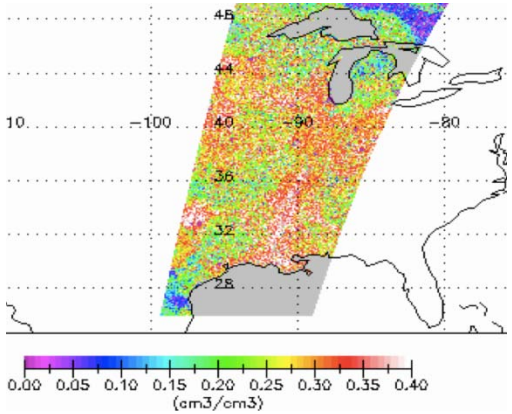
L1C_S0_Hi-Res Radar
Backscatter Product (1-3 km)



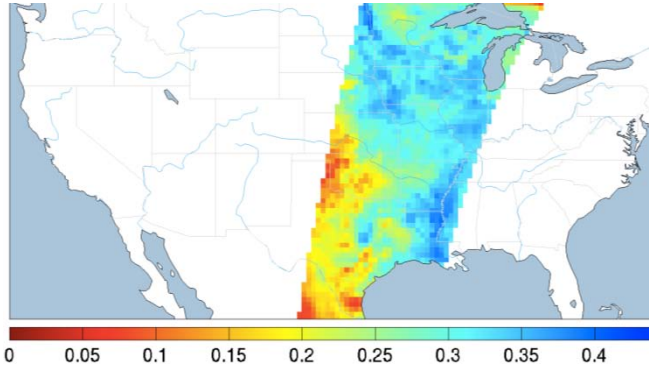
L1C_TB Radiometer
Brightness Temperature Product (36km)



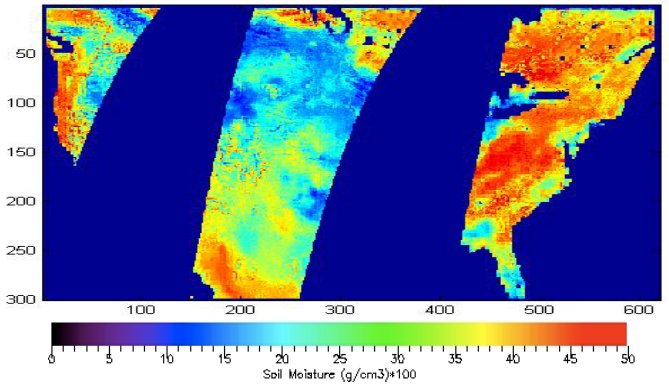
L3_SM_A Radar
Soil Moisture Product (3 km)



L2_SM_P Radiometer
Soil Moisture Product (36 km)



L2_SM_AP Combined
Soil Moisture Product (9 km)



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SMAP Working Groups

Working Groups have been established as a means to enable broad science participation in the SMAP mission. The working groups are led by Science Definition Team (SDT) members. The working groups communicate via periodic workshops, E-Mail and at conferences and other venues.

There are four current working groups:

1. Algorithms Working Group (AWG)
2. Calibration & Validation Working Group (CVWG)
3. Radio-Frequency Interference Working Group (RFIWG)
4. Applications Working Group (ApWG)

http://smap.jpl.nasa.gov/science/wgroups/

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SMAP

SOIL MOISTURE ACTIVE PASSIVE

SMAP will provide high-resolution, frequent-revisit global mapping of soil moisture and freeze/thaw state to enable science and applications users to:

- Understand processes that link the terrestrial water, energy and carbon cycles
- Estimate global water and energy fluxes at the land surface
- Quantify net carbon flux in boreal landscapes
- Enhance weather and climate forecast skill
- Develop improved flood prediction and drought monitoring capability

SMAP data will be used in applications of national significance that range from agriculture to human health.

Join us for the SMAP Application Discussion
@Moscone Center South
End of row Z
Wednesday, December 15th, 2010 at 12:00 pm
(Immediately following the poster session)

www.nasa.gov

http://smap.jpl.nasa.gov

Backup Slides

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Mission Science Objective

Global mapping of Soil Moisture and Freeze/Thaw state to:

- Understand processes that ***link*** the terrestrial water, energy & carbon cycles
- Estimate global water and energy fluxes at the land surface
- Quantify net carbon flux in boreal landscapes
- Enhance weather and climate forecast skill
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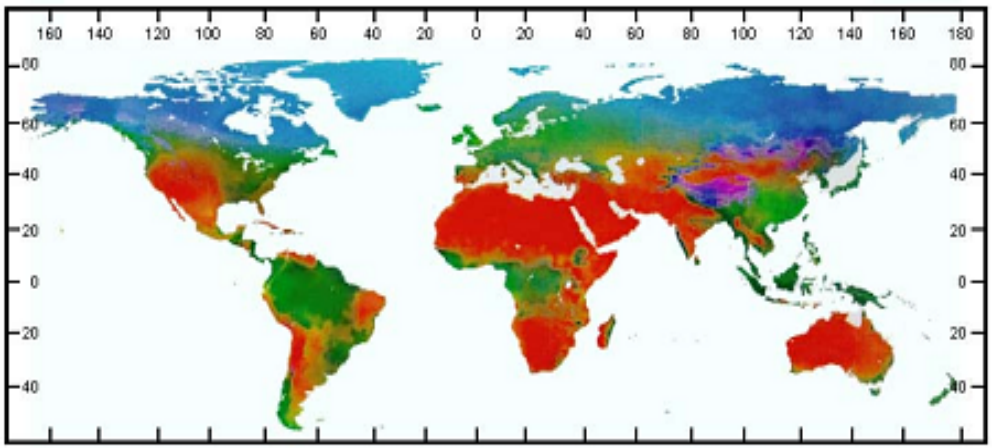

Primary Controls on Land Evaporation and Biosphere Primary Productivity